ON THE STRATIGRAPHY, FOSSILS AND GEOLOGICAL RELATIONSHIPS OF THE LAMETA BEDS OF JUBBULPORE. BY C. A. MATLEY, D.Sc, F.G.S. (With Plates 16 to 18.)

I—INTRODUCTION.

THE group of fresh-water sedimentary rocks known as the Lameta formation is principally developed in the Central Provinces of India, where its outcrop can be followed for some hundreds of miles as a narrow fringe to the lower boundary of the overlying Deccan Trap. The formation, in spite of its persistence and wide extent, is a thin one, the thickness being stated to vary from 20 to 150 feet.[1] The age of these beds, though not closely fixed, is generally regarded as Middle Cretaceous (Cenomanian-Turonian). As the lower beds of this formation in the Dhar Forest area have been described as the fresh-water equivalent of the marine Cretaceous Bagh beds,[2] which have recently been shown from the evidence of the echinoidea to be of the age of the English gault (Albian),[3] they may be slightly earlier than Cenomanian.

Although there are excellent general descriptions of the Lameta beds in the Manual of the Geology of India and other publications of the Geological Survey of India, little detailed study appears to have been given to this group of rocks until recent years, except in the neighbourhood of Jubbulpore, where they were examined in some detail by H. B. Medlicott in 1872.[4] He announced the following conclusions as the result of his mapping of this district:—

(*a*) The Lameta beds are irregular deposits and no constant sequence or composition can be given. "A limestone is its only general characteristic; sometimes forming the whole of the band, sometimes quite subordinate in detrital deposits." (*Op. cit.*, p. 117.)

[1] Manual, Geol. of India, 2nd edition (1893), p. 264.

[2] *Genl. Rep. Geol. Surv. India* 1902-03, (1903), para. 50, page 20.

[3] R. Fourtau, Les Echinides des "Bagh Beds." *Rec. Geol. Surv. India*, Vol. XLIX, (1918), pp. 34-53.

[4] "Note on the Lameta or Infra-trappean Formation of Central India" (*Rec. Geol. Surv. India*, Vol. V, pp. 115-120.) The area around Jubbulpore must be regarded as the type area of the formation, the name of which is taken from Lameta (Lamehti Ghat, on the Narbada, a few miles south-west of Jubbulpore.

(*b*) Contemporaneous denudation has assisted the irregularity of deposition so as to admit the top and bottom beds of the group coming together within a short distance (*Op. cit.* p. 118).

(*c*) The Lameta group rests, with a discordance, upon the Jabalpur group of Upper Gondwana age, the former passing indiscriminately across the latter elsewhere, and even here an inlier of Jabalpur sandstone is weathered out from the surrounding Lameta limestone. (*Op. cit.* p. 116.)

(*d*) "There is good evidence for a slight pre-trappean disturbance of" the Lameta group. (*Op. cit.* p. 118.)

(*e*) "There is conclusive evidence for pre-trappean denudation." (*Op. cit.* p. 118.)

During a recent visit to Jubbulpore, I was able, with the aid of an excellent contoured map of the cantonment on the scale of 16 inches to the mile, to carry out a detailed geological survey of a large part of Jubbulpore cantonment. The sequence and geological structure of the Lameta beds and their relationships to the rocks above and below them have by this means been elucidated in a manner which would hardly have been possible to a geologist working, as Medlicott did, with a map on the one-inch scale, and the result has been to clear up a number of difficulties in the stratigraphy and substantially to modify Medlicott's conclusions. The Lameta beds are found to occur in regular sequence; there has been little contemporaneous denudation, the appearance of the top and bottom beds of the group coming together being due to strike-faulting concealing the intervening beds. The Lameta group rests conformably on the Jabalpur group in the area mapped, and it is also conformable with the Deccan Trap, except that there may have been in places a little erosion of the highest Lameta zone. No disturbance of the Lameta group prior to the pouring out of the traps was traced, all the faults and flexures mapped being post-trappean.

II.—DESCRIPTION OF THE ROCKS.

The sequence of rocks in this area is as follows, in descending order:—

D.—Deccan Trap.

C.—Lameta group.

(*e*) Upper Sands.
(*d*) Upper Limestone (a local zone).
(*c*) Mottled Nodular Beds.
((*b*) Main or Lower Limestone.
(*a*) Greensand.

B.—Jabalpur group.

(*b*) White Clays.
(*a*) Sandstones.

A.—Ancient crystalline rocks, on which the Jabalpur sandstones rest with a strong unconformity.

The *Jabalpur Group* consists, as regards the lower beds, of thick soft yellow, brown or white sandstones, falsely, and irregularly bedded. They are usually free from pebbles, but a conglomerate bed was seen near their junction with the old crystalline rocks. These sandstones pass up into fireclays and soft argillaceous and sandy shales with subordinate seams of white sandstone, this part of the group being usually white but sometimes tinged purple or red. Owing to the contrast in their colour and texture to the sandstones above and below them, the white clays can be traced in the field with little difficulty. They are of economic value and are worked on a large scale by Messrs. Burn & Co. for the manufacture of fire-bricks, tiles, pipes, etc. A seam of coal has been recorded[1] as occurring in a well in the old jail compound, at a depth of 70 feet probably at or near the base of the formation, but no outcrop was met with in my mapping. It is probably overlapped along the granitic boundary.

The *Lameta Group* consists of the five zones indicated in the above table. Its thickness varies in the area mapped from 160 to 70 feet. It is essentially a sandy formation, grains of sand occurring abundantly throughout its thickness. The *Greensand* forms the lowest zone. It is a soft false-bedded friable sandstone, usually of a green colour, pale when dry, of a deeper green tint when wet, but this distinctive colour is often absent, and there is then a difficulty in distinguishing this zone lithologically from the Jabalpur sandstones. A few tiny pebbles, mostly of quartz, occur in it. At times it becomes a hard rock with a ferruginous cement and occasionally, as at

[1] H. B. Medlicott. "Notes on the Satpura Coal-basin." *Mem. Geol. Surv. India*, Vol. X, (1873), p. 142

Burn & Co.'s clay-pits, it shows near the base a wide range of colours like the well-known variegated sands of the cliffs of Alum Bay (Isle of Wight). In the area mapped it lies invariably upon the white clays of the Jabalpur group, the junction being often marked by a hard irony or ochreous layer due to the alteration of the sand by the action of percolating water arrested at this level by the impervious clays below. Its thickness varies considerably, being sometimes as much as 45 or 50 feet, sometimes as little as 7 feet.

The *Main or Lower Limestone* is variable in composition. It is a light-grey, cream-coloured or bluish limestone, usually containing sandy material, pebbles of jasper, quartz and other rock fragments, and irregular seams and nodules of chert. Sometimes it is so sandy as to become a calcareous sandstone, but more often is pure enough to be burnt for lime. The material unfit for lime-burning is also quarried for road-metal. Ordinarily the limestone is concretionary, and at times it has at the top a conglomeratic layer of large pebbles including some of limestone evidently derived from the underlying bed by contemporaneous denudation. The limestone is from 3 to 12 feet thick, and even thicker to the east of Bara Simla. Over the eastern part of the ground mapped I found that a thickness of 8 feet was usually quarried. Owing to its resistance to denudation it forms conspicuous escarpments and wide shelves of bare, or nearly bare, rock.

Mottled Nodular Beds.—The above-described limestone is succeeded by a set of red, green and mottled sandy and clayey beds usually 40 or 50 feet thick, characterised by their many sandy and calcareous concretions, which give to the beds when disintegrated by weathering the appearance of a coarse rubble. They are rarely laminated. Some bands contain few or no concretions, and the general aspect of these, both as regards colouring and texture, reminds me of the Keuper marls of the Midland Counties of England. Small pebbles occur sparingly throughout. In their upper part the beds usually become more sandy. Some of the bands approximate to very impure nodular and sandy limestones.

Upper Limestone.—This zone, which seems to be quite local, forms the top of the Mottled Nodular Beds. It is not nearly so pure or constant as the Lower Limestone, and, unlike the Lower Limestone, is not quarried. It is generally extremely sandy and is more often a calcareous sandstone than a limestone. In the south-eastern part of the area mapped it forms a strong band 10 feet thick but usually

it is thinner, though generally mappable because owing to its hardness it forms a small escarpment. The passage into this zone from the Nodular Beds is at times very gradual.

Upper Sands.—The Upper Limestone is usually covered by buff and brown sands, sometimes 15 to 20 feet thick, though the thickness is often obscure owing to the outcrop being more or less concealed by talus from the overlying Deccan Trap. The zone is, however, sometimes quite thin ; it is uncertain whether the whole of the deposit is then present in an attenuated form, or whether some of it was removed by penecontemporaneous erosion before it was covered up by the Deccan Trap.

The Deccan Trap lies conformably on the Lameta deposits. At several localities where the junction was examined no contact alteration was to be seen. At one place, near the Limekiln Blockhouse, a bed of fine grained quartzite lies just below the Trap and its silicified condition may be due to the hydrothermal action of the overlying lava on the soft sands.[1] It may be mentioned that the lowest lava shows good columnar structure in a road-cutting east of Pachperi.

III—.STRATIGRAPHICAL DETAILS.

The area mapped in detail is about 4 square miles in extent and lies about two miles east of Jubbulpore City. The middle of this area is occupied by a flattish ridge (the Pat Baba ridge) about 1,450 ft. O. D. which runs E. N. E. and rises at either end into low hills. The highest point is at the eastern end of the ridge (Karaundi Hill, with two peaks, 1,625 and 1,600 feet) adjoining which is a peak, about 100 feet lower, crowned by a blockhouse known as Limekiln Blockhouse. At the western end of this ridge is Bara Simla (1,600 feet) and Chhota Simla (1,525 feet) on each of which a blockhouse has been erected.[2] There is also an isolated trap-capped hill, Chui Hill (1,555 feet), so named from the clay-pits that surround it, about one-third of a mile north-east of Chhota Simla.

The Pat Baba ridge lies below the horizon of the Deccan Trap but all the above-mentioned hills, with the exception of Chhota Simla, are capped with outliers from 10 to 130 ft. thick of the lowest lavas of that formation. The lower ground to the north of Pat

[1] See microscope slide No. 12860 in the collection of the Geological Survey of India.

[2] The trap-capped hill called Chhota Simla in Medlicott's paper of 1872 is evidently the hill now known as Bara Simla. The lower hill marked in the maps of the present day as Chhota Simla has no capping of trap.

Baba Ridge is the site of the Government Gun Carriage Factory. Lameta and Jabalpur beds occur here, the latter resting on the ancient granitic rocks whose picturesque steep rocky slopes stand out conspicuously less than a mile away to the north-west. The ground to the south of the Pat Baba Ridge is the basin of the little Marjadlia stream. The stream-course is cut mainly through the Jabalpur series while the south-eastern slope of the valley rises through the Lameta beds to the main Trap escarpment of the district.

The strata rarely dip more than a few degrees. The dip is generally at a low angle to the N. N. W., but its effect is largely or completely counteracted by a number of parallel strike-faults that run in an E. N. E. directon and have their downthrow on the south side. The strata are also affected by a number of gentle flexures. The most northerly of the strike-faults may be designated the *Factory Fault* as it passes through the Gun Carriage Factory. It can be traced in several nullas E. N. E. of the Factory where it brings the mottled nodular beds against the Jabalpur clays and sandstones. It probably has a displacement of 60 ft. or so and appears to die out to the W. S. W. The next important fault (Pat Baba fault) skirts the northern edge of the Pat Baba plateau, passes near the Limekiln Blockhouse and descends the northern slopes of Karaundi Hill. It throws down the traps and the underlying beds on the south to the extent of 30 to 40 feet. This fault also appears to die out to the W. S. W. before reaching Bara Simla. The third fault may be termed the *Marjadlia Valley Fault;* it displaces the outcrops of the Main Lameta Limestone and associated beds and in places brings the Lametas on to the same level as the Jabalpur rocks. As the greensand here is less than its normal thickness it is probable that its throw nowhere exceeds 20 feet. The fourth fault may be designated the *Trap Escarpment Fault*, it throws down the traps against the Lameta beds. In the north-eastern part of its course it cuts out the whole of the Lametas and the throw there cannot be less than 70 feet and may be considerably more; but the throw diminishes rapidly as the fault-plane is traced to the south-west where the upper zones of the Lametas (Upper Sands, Upper Limestone and Nodular Beds) are seen to crop out below the Trap and to be thrown against the Main Limestone. The fifth and last of these faults cuts off the curved outcrop of the three highest zones of the Lametas and throws them against the Traps. As the lowest lavas of the Deccan Trap are also cut out

by it this fault probably has a considerable throw. From an inspection of the old one-inch geological map it seems likely that this system of faults extends for some miles to the north-east crossing the Kundam Road in the neighbourhood of Jhirria. Several more faults of small throw have been detected and are shown on the map. One of them, near the Factory, is exceptional in that its downthrow is to the north.

An inspection of the map accompanying this paper will show that all the zones from the Jabalpur sandstone to the Deccan Trap are present in their recognised order throughout the area surveyed, indicating that the whole sequence is a conformable one. Attention was given to the junction of the Lametas with the Jabalpur beds with a view to detecting an unconformity at this horizon, if one exists. I found that the junction usually ran evenly along the uneroded surface of white clay beds, that there were no conglomerates or fragments of white clay at the base of the greensand and that undulations in the clays below the junction were continued into the overlying greensand, showing that the flexures were of post-Lameta date. In two places, however, exposed in Burn & Co.'s clay-pits, the greensand lies on an eroded channel in the clays, the channel being a few inches deep in one case and as much as 4 feet in the other. The erosion seems to me to be contemporaneous or nearly so and merely indicates that the currents that deposited the current-bedded Lameta greensand were powerful enough to erode channels in the recently formed clays. The field evidence therefore is strongly in favour of the view that the Lameta formation succeeded the Jabalpur clays after a very short interval, as it is improbable that these soft clays could have resisted complete denudation for any considerable length of time.

The close connection of the Lameta beds with the overlying trap has been recognised by almost all writers on the subject, and it is clear from the field evidence that the lowest lava flows must have been erupted very soon after the deposition of the Lametas.

IV.—EVIDENCE FROM THE NEIGHBOURING DISTRICT.

A tour of a fortnight's duration was made by me in February 1919 into the country to the north-east of Jubbulpore as far as the Mahanadi, principally with the object of searching for remains of dinosaurs in the Lameta beds, but some attention was also given to the sequence of the Lameta deposits. The exposures were on the whole

much less satisfactory then in the area mapped, as the upper Lametas lie on the steep forest-clad slopes of the trap escarpment and are more or less concealed by a talus of basalt blocks while the lower beds which occupy flatter ground are also frequently obscured by an alluvial deposit containing many boulders of trap washed down from the neighbouring hills. Exposures have generally to be looked for in the nullas.

The most complete and satisfactory section was that seen chiefly in a nulla, near the village of Amakhoh, about 8 miles E.N.E. of Bara Simla. The Jabalpur sandstone, with white clays overlying it is well exposed in the nulla which for some distance follows the junction of the clays with the sandstone. The clays here are only a few feet thick and are more sandy than at Jubbulpore but there can be no question that they are the same as the Jabalpur clays. They pass up, apparently conformably, into thick false bedded sandstones (the *Greensand*) at the top of which some pieces of dinosaurian bones were found, more pieces being also found lying loose in the bed of the nulla. The Main or Lower Limestone occurs in its expected position lying on the sandstone. It is here a good limestone quarried both as a building stone and for lime. Above it were found the typical red and mottled concretionary beds with calcareous bands passing up into sands on which lie the Deccan Traps. There is no contact alteration at the Trap junction. This section is of special interest because:—

(*a*) it shows that all the zones from the Jabalpur sandstone to the Trap found at Bara Simla (except the local Upper Limestone) are present and occur in the same order 8 miles away, and

(*b*) it supports the view of a conformable succession from the Jabalpur group to the Deccan Trap.

As the journey from Jubbulpore to the north-east is continued the typical Jabalpur sandstones and clays seem to disappear and have probably been overlapped by the Lameta beds. The rocks to the north and north-east of Silondi shown on the map accompanying Mallet's paper in Vol. XVI of the Records as "Upper Gondwana" and on the original maps as Jabalpur beds are of a different character and appear to be older than the true Jabalpur group. To these local Gondwana rocks the basal Lametas are distinctly unconformable as will be shown later.

As regards the upper beds of the Lametas the sequence from the Main Limestone upwards seems to be fairly constant in the north-eastern area and to agree substantially with that in the Bara Simla region. The beds below the Trap were found to be always sandy, being sometimes a good clean sand, sometimes a loamy sand, sometimes a hard sandstone near the Trap junction, due probably to contact alteration. They pass down into concretionary and calcareous marls which rest on the Main Limestone. The latter will probably be found to be a constant zone over all this area; it is frequently exposed in nullas and around villages and occasionally it forms rocky shelves and escarpments like those seen on the Pat Baba Ridge near Bara Simla. A good example of this occurs between Dadar Sihondi and Umarpani. Two sections in these upper beds are given below:—

South-west of Sagona.

D. Trap (no contact alteration at base).
C. Lameta beds.

(*e*) Sands interlaminated with bands of red sandy clay—about 25 ft.
(*c*) Calcareous nodular beds with intercalations of softer mottled clayey sands.
(*b*) Thick limestone.

2½ miles east of Silondi at western end of trap-capped spur.

D. Trap (no contact alteration at base).
C. Lameta beds.

(*e*) Sands, clean, with rare seams of clayey sand 40 to 50 feet. (They contain dinosaurian bones.)
(*c*) Impure nodular and sandy limestones about 10 feet. Purple and green marls 8 to 10 feet.
(*b*) Thick limestone, 10 to 12 feet.
Nodular limestone, 6 feet seen.

As regards the beds below the Main Limestone, the basal Lametas were rarely seen in my traverses across this country, but they were met with in two sections which are worth describing. The first is near Bijjain, 20 miles north-east of Jubbulpore, the other is about 17 miles east of the first, to the north-east of Silondi. In a large nulla in the neighbourhood of Bijjain, near the boundary

with the Bijawar rocks on which that village stands, there is a pebble-bed or conglomerate, 10 feet or more in thickness, crowded with jasper and quartz pebbles together with pebbles of other rocks. At one place it encloses a lenticular band of soft sandstone, and at another place a long band, about 3½ feet thick, in parts, of laminated whitish sandy clay, much of which is stained yellow. This conglomerate, which presumably lies on the Bijawar rocks (though I did not explore the nulla far enough to find the junction) appears to be the shore-line representative of either the Jabalpur group or the greensand of the Lameta group. The presence of the whitish clay possibly indicates the former. Further from the Bijawar boundary a thick zone of hard conglomeratic limestone is seen, full of pebbles of all sizes, jasper pebbles being very abundant and conspicuous.

The other good section showing the basal beds of the Lametas occurs to the north-east of Silondi between Khuropani and Majhgawan, where an irrigation reservoir was under construction at the time of my visit. Below the dam are hard Gondwana sandstones and grits; they are shown as Jabalpur beds on the Survey map, but they are not at all like the sandstones of the Jubbulpore area. Above the dam at the northern edge of the reservoir the ground was being cleared and levelled and showed excellent exposures of hard Gondwana sandstones interstratified with flaggy beds of soft sandstone dipping in various directions in many gentle undulations. Lying quite unconformably on their eroded edges is a gravel composed mainly of well-rounded quartz and jasper pebbles; a thickness of a foot or so has been left in many parts of this levelled area, and a greater thickness 3 or 4 feet occurs in the bank cut at the edge of the tank. No Lameta or Trap fragments were found in this gravel which closely resembles the pebble-bed near Bijjain, though it is overlaid by a deposit containing boulders, etc., of Trap and Lameta rocks. The gravel is probably the basal bed of the Lameta group, but there is just a possibility that it may be a post-Trappean alluvial gravel, and it might therefore be unsafe to deduce an unconformity between the Lametas and these Gondwanas on this evidence alone. Any doubt, however, on this point is set at rest when the slope of the adjacent trap-capped hill is examined. Hard Gondwana sandstone is seen at the foot of the slope. Above it is a conglomeratic Lameta limestone containing not only the usual quartz and jasper pebbles but large angular pieces of one of the most typical and hardest of the underlying Gondwana beds, a tough siliceous grit of vitreous aspect

made up of quartz grains in a yellow silliceous paste.[1] It shows unmistakably that the Lametas are unconformable with the Gondwana beds of this area. The succession above this conglomeratic limestone can be followed up to the Trap. More calcareous beds are seen, often pebbly, some being nodular while one is of a less nodular type. The limestones form two scarps on this hill side, and the series is capped by trap, just below which (as seen on the far side of the ridge) is a coarse sandstone. The top sandy zone of the series is therefore present here as usual. It is noteworthy that the two types of basal deposits seen near Bijjain, (1) Pebble beds of quartz and jasper, and (2) conglomeratic limestone, occur here also, again near the old shore-line, although the two localities are 17 miles apart.

From an examination subsequently made of the type-section of the Lameta formation near Lameta Ghat, about 9 miles south-west of Jubbulpore, I find that the Lametas there are separable into five zones that can be correlated zone by zone with the succession at Jubbulpore. A fuller account of them is given in a separate paper. It may be remarked that no trap dykes penetrating the Lameta or Jabalpur beds were met with during my field-work.

V.—FOSSILS.

The earliest discovery of fossils in the Lameta formation was made in 1828 at Jubbulpore by Major-General (then Captain) Sleeman, the suppressor of *thagi*. He resided at that time at Jubbulpore and he records in his "Rambles and Recollections of an Indian Official" (page 98 of 1915 Edition). "I went first to a hill within sight of my house in 1828, and searched exactly between the plateau of basalt that covered it and the stratum immediately below, and there I found several small trees with roots, trunks and branches, all entire and beautifully petrified. They had been only recently uncovered by the washing away of a part of the basaltic plateau. I soon after found some fossil bones of animals." Sleeman's fossil bones were sent by Dr. Spilsbury, Civil Surgeon of Jubbulpore, to Calcutta in 1832, where they were examined by James Prinsep, who reported that they were "too mutilated to be pronounced on but their osseous structure is apparent."[2] Sleeman's account seems to indicate that the fossils were discovered at the top of the Lametas

[1] See microscope slide No. 12859 in the collection of the Geol. Survey
[2] *Journ. As. Soc. Bengal*, Vol. I, (Oct. 1832), pp. 456-7.

immediately below the basalt, but Spilsbury's description and geological section are sufficiently clear to show that they came from the conglomeratic top of the Main Limestone of Bara Simla Hill, the limestone forming at that time a ledge or platform which has since been quarried away. Other specimens were found in the limestone itself and some may have come from a conglomeratic band near the top of the greensand zone.[1] Although Spilsbury did not doubt that Bara Simla Hill was "most rich in fossil remains from the quantity and fragments of trees and bones strewed about,"[2] nearly all the specimens collected were very imperfect and fragmentary, and when Lydekker, forty years later, examined the material available at that time, the only specimens found worthy of description were two posterior caudal vertebræ (previously figured and described by Falconer) and an imperfect femur found at a later date. These he identified as belonging to a sauropod dinosaur allied to the English genus *Cetiosaurus*, and he made them the type of a new genus and species, *Titanosaurus indicus*.[3] The femur, however, as can be seen from the siliceous matrix in which the specimen lies, did not come from the same bed as the vertebræ. It cannot, therefore, belong to the same animal and may not even be of the same genus.

No further specimens seem to have been discovered since 1877 until, in October 1917, I found on the western slope of Bara Simla Hill a number of bones of a sauropod dinosaur in a good state of preservation and a considerable portion of the skeleton of a carnivorous (theropod) dinosaur. Excavations were afterwards made under my supervision in this fossiliferous ground by and at the expense of the Geological Survey of India with the help of a Field Collector whom the Director kindly detailed for the work. Further specimens were thus obtained and all the collections are now in the Indian Museum. The locality is a small area on the western slope of the hill close to the track leading up to the Blockhouse and about 100 yards from the bungalow and office of the Inspector of Gun Carriages and Vehicles. The bones were all found near the horizon of the Main Lameta Limestone, but at several levels, as mentioned below.

[1] *Journ. As. Soc. Bengal*, Vol. II. (Nov. 1833) pp. 583-88.
[2] *Journ. As. Soc. Bengal*, Vol. VI, (June 1837), p. 437.
[3] *Rec. Geol. Surv. India*, Vol. X. (1877). p. 38, *Pal. Ind.*, Ser. IX. Vol. I, part 3, 1879), p. 20; Falconer's Palæontological Memoirs and Notes, Vol. I, (1868), p. 418.

A trench was dug along the conglomeratic top of the limestone and numerous fragmentary bones of sauropod dinosaurs were found lying among the pebbles and small boulders. This bed is no doubt the "gravel or alluvial conglomerate" from which Sleeman's and Spilsbury's early collections were obtained. From a coarse deposit of this character good specimens are likely to be of rare occurrence.

The best sauropod bones occur in a red and green marly clay about 4 feet above this conglomerate. Here many important and hitherto unknown parts of Indian dinosaurs were found. The collection includes a right scapula (66 inches long), left scapula, right humerus (53 inches in length), radius, ulna (?), fibula, left ischium, (45 inches long), a large number of broken ribs, fragments of a sacrum, three caudal vertebræ, and several large chevron bones (16 to 18 inches in length). Should it be decided to follow up this stratum by further excavation into the hillside more bones will in all probability be obtained. The bones did not lie in the clay in their natural relative positions; they had been washed about and somewhat damaged and broken before fossilisation. With them were found a smaller humerus of a different type, a vertebra, and a number of teeth of a carnivorous dinosaur, like those of *Megalosaurus*. The sauropod bones, when completely examined, will form the subject of a separate paper, but it may be stated that the reptile to which the large bones belonged was probably not less than 60 feet in length. The three caudal vertebræ belong to *Titanosaurus indicus*, and if the large bones found in the same bed can be referred to the same reptile, Lydekker's view that *Titanosaurus* is a true sauropod will be confirmed. As some European and South American forms assigned to this genus have been declared by Nopcsa not to belong to the Sauropoda but to the Trachodontid Orthopoda it would appear that in spite of their *Titanosaurus*-like caudal vertebræ they do not belong to the Indian genus.[1]

The third horizon that has yielded dinosaurian remains is the top of the greensand zone. At a spot about 50 yards to the south-east of the area in which the *Titanosaurus* bones occurred a large mass of bones was found immediately below the Main Limestone. The bones first obtained were found to belong to a carnivorous (theropod) dinosaur about 20 feet or more in length and allied to *Megalosaurus*.

[1] Nopcsa. "On the systematic position of the Upper Cretaceous Dinosaur *Titanosaurus*. *Geol. Mag.*, 1910, p. 261.

Unfortunately part of the bone-mass was destroyed when the limestone was quarried many years ago, as a number of vertebræ and many fragments have been recovered from the old spoil bank. Much of the material is also crushed and broken owing to the bones being hollow. The greater part of the bone-mass has since been excavated and the work of developing and cementing of the bones is being proceeded with. The bulk of the material, and possibly the whole, belongs to two or more megalosaurians. The collection is a large one and contains about 100 vertebræ, 20 chevron bones, two sacra, pelvic bones, ribs (including abdominal ribs), a number of limb bones, about 70 phalanges, several carpals, metacarpals, metatarsals, etc., various parts of the skull, including several portions of upper and lower jaws and many detached teeth. About 5,000 scutes, of many shapes and sizes, the great majority of which are small, ranging from $\frac{1}{8}$ to $\frac{3}{4}$ inch in length, were found among the bones; but others are larger, varying from 1 to 3 inches in longer diameter, one being 5 inches long. They indicate that one or more of the associated reptiles was protected with dermal armour.[1] The discovery of this deposit is of importance, apart from the special interest of the dermal plates, because the only carnivorous dinosaurian remains hitherto found in India are a few teeth ascribed to *Megalosaurus sp.*

A humerus of a sauropod and some other bones were found by the Field Collector, Mr. D. S. Bhattacharji, in a small nulla, about 40 yards away from the Megalosaurian bone-mass, in the greensand, at about two feet below the limestone. They occur in a thin pebbly seam in which a good deal of siliceous cementation has taken place and it is almost impossible to extract the bones from the silicified matrix. It is probable that the imperfect femur assigned by Lydekker to *Titanosaurus indicus* was derived from this seam. At the same level, but at some distance away in a nullah on the eastern slope of Chhota Simla Hill, a large vertebra (probably of a theropod) and another large but rotten bone were found. A number of pieces of both sauropod and theropod bones were also seen lying on the adjacent slopes, so that the bone-bearing beds appear

[1] *Cf. Tyrannosaurus* (*Dynamosaurus*) *imperiosus* from the Cretaceous rocks of Wyoming, described by Osborn as possessing scutes (*Bull. Amer. Mus. Nat. Hist.*, Vol. XXI, (1905), pp. 259-265). A few dermal ossifications have also been found with *Ceratosaurus nasicornis*, *vide* Gilmore, "Osteology of the Carnivorous Dinosauria, &c."—*U. S. Nat. Museum, Bulletin* 110, (1920), pp. 113-114.

to have been at one time continuous from Bara Simla to Chhota Simla, the intervening portion having since been removed by erosion. In other parts of the area mapped fossils seem to be quite rare. Two pieces of bone (silicified) were, however, found at the base of a little outlier of the limestone, 1¼ miles east of Bara Simla.

In spite of the wide distribution of the formation, the Lameta beds have hitherto yielded dinosaurian remains at three localities only, widely separated one from another, namely Jubbulpore, Pisdura, and Kareia. From Pisdura, about 200 miles away from Jubbulpore, in the Chanda district, Lydekker has described some caudal vertebræ (*Titanosaurus blanfordi*) and a chevron bone (*Titanosaurus* sp.) and he mentions that other bones, mostly fragmentary, were found there.[1] As regards Kareia, Medlicott stated that "large vertebrate remains though scarcely perfect enough for identification have been found" in the bed of the Sher river, under the village of Kareia about 40 miles W. S. W. of Jubbulpore.[2] In February 1919 I spent a fortnight in the country to the north-east of Jubbulpore as far as the Mahanadi river, about 40 miles away, examining the Lameta outcrops, mainly with the object of seeing whether more fossils could not be obtained. The result was that pieces of dinosaur bones (all of them probably belonging to the sauropoda) were discovered at a number of new localities, mostly as loose surface specimens, but in three places they were found *in situ*. Unfortunately nearly all the specimens were fragmentary, but one nearly complete limb bone, 60 inches in length, was found, though in a fragile and rotten condition. On the accompanying sketch map (Plate 16) the places in the Jubbulpore district that have now yielded remains of dinosaurs are marked with numbers. Details are as follows :—

(1) *Jubbulpore Cantonment.* (*Bara and Chhota Simla*).—Many remains, as described above.

(2) *Jubbulpore Cantonment.* (1¼ *miles east of Bara Simla*).—Two silicified pieces, as mentioned above.

(3) *Amakhoh.*—(11 miles from Jubbulpore). Fragments were found in the top of the greensand of the nulla section. Two larger pieces washed down the nulla were found in the bed of the stream.

(4) *1½ miles south of Bijjain.*—One piece (silicified) found.

[1] *Pal. Ind.*, Ser. IV, Vol. I, part 3.
[2] *Rec. Geol. Surv. India*, Vol. V, (1872), p. 119.

(5 to 8) *Sagona and neighbourhood :—*

(5) $2\frac{1}{4}$ *miles S. S. W. of Sagona.*—Four pieces found loose lying on upper beds of Lametas.

(6) $\frac{1}{8}$ *mile south of Sagona.*—Large crushed and broken bone in a red clay above the Main Limestone. Several more pieces found within $\frac{1}{4}$ mile of this spot.

(7) $1\frac{1}{2}$ *mile W. S. W. of Sagona.*—One piece found loose. Horizon not far below the Trap.

(8) *Kothi, 2 miles East of Sagona.*—Minute fragments of bone in beds above limestone.

(9) *2 miles west of Dadargaon.*—One piece, above Main Limestone.

(10) $2\frac{1}{2}$ *miles east of Silondi,* at western end of trap-capped spur. (See section described on page 151). The Upper Sands yielded a large limb-bone, 60 inches long, and several smaller bones were also found in a bad state of preservation.

The result of this search is to show that, in the Jubbulpore district at any rate, remains of dinosaurs are widely but sparingly distributed and occur at various horizons in the formation, though perhaps more commonly above the Main Limestone than below it.

From Sleeman's account quoted on pages 152-153 and from the fact that Spilsbury stated that the bones first found by Sleeman came from near "where the petrified tree was discovered which is in the museum"[1] it is clear that fossil wood occurs in the Lametas of Jubbulpore. Medlicott also mentions[2] that silicified wood is "common in the Lameta beds." It is therefore curious that of all the fossils found by me in this district there is not one that I can definitely state to be fossil wood.

VI.—AGE OF THE JABALPUR AND LAMETA BEDS.

The opinions generally held as to the ages of the rocks described in the foregoing pages are that the Jabalpur beds are Middle Jurassic, the Lametas either Middle Cretaceous or highest part of the Lower Cretaceous, and the lowest Deccan Trap highest Cretaceous or early Tertiary in age, and though the palæontological evidence in support of these relative ages is not strong no objection can be taken to them on stratigraphical grounds so long as H. B. Medlicott's view is accepted that there are unconformities

[1] *Journ. As. Soc. Bengal,* Vol. I, (1832), pp. 456-457).
[2] *Mem. Geol. Surv. India,* Vol. II, (1860), p. 199.

at the bottom and the top of the Lameta formation. The field evidence given in this paper, however, seems to show that the deposits from the base of the Jabalpur beds up to and including the Deccan Trap are arranged in an almost continuous and conformable sequence, and that such breaks as are found to exist in the continuity of the beds are of an unimportant character due to contemporaneous erosion and represent very short intervals of geological time. As the Jabalpur and Lameta groups have a combined thickness of only a few hundred feet and consist of fresh-water deposits largely arenaceous in composition and almost certainly of rapid deposition it is difficult to understand how they together with the lowest Traps overlying them can range through so large a portion of geological time as from the Middle Jurassic to highest Cretaceous. For this reason it is very desirable that the evidence on which the relative ages of the formations have been assigned should be re-examined. The Lametas, as previously stated, are believed to be approximately of Cenomanian or Albian age because they have been shown by the work of the Geological Survey in the Dhar Forest region to be the fresh-water equivalents of the marine cretaceous Bagh beds. The palæontological evidence in confirmation of this correlation is at present weak but not contradictory. It depends almost entirely on the dinosaurian remains because the plant remains known to occur in the Lametas have not been identified, the mollusca are very rare and the few fish remains discovered long ago east of Warora are of little zonal value. As regards the dinosaurs found in the Lametas, *Megalosaurus* ranges from the Lias to the Danian, but the carnivorous dinosaur found at Jubbulpore, though a megalosaurian closely allied to *Megalosaurus*, will probably prove when fully examined to belong to a different genus. *Titanosaurus* has been recognised in Madagascar and East Africa [1] in rocks of Cenomanian-Turonian age. The genus has also been identified in England in Wealden beds and in South America and France in beds of Danian age. There is however considerable doubt whether the genus persists so late as the Danian because the South American and French forms are probably not congeneric with the *Titanosaurus* of India and may not even belong to the Sauropoda. In fact, according to the American palæontologist R. S. Lull, the Sauropoda became extinct soon after

[1] At Tendaguru, *vide* R. S. Lull—"Dinosaurian Distribution".—*Amer. Journ. Sci.*, Vol. XXIX, (1910), p. 27. I have however not yet discovered the reference in the original literature.

Wealden times, and *Titanosaurus* must therefore have been one of the very last survivors. The assignment of the Lameta Beds to the top of the Lower Cretaceous is, therefore, probably approximately correct. The few mollusca found in the Lametas are insufficient to determine the age of these beds with any precision though they seem to indicate that the rocks are Cretaceous. In the Chhindwara district Dr. Fermor found one specimen having some resemblance to the fresh-water genus *Melania* (recorded as *Turritella ?*) and numerous specimens of *Paludina* (*Rec. Geol. Surv. India*, Vol. XLIII, 1913, p. 33). At Pisdura, near Warora in the Chanda district, *Physa Prinsepii* [1] was found associated with dinosaurian bones and remains of other vertebrates, but some doubt has been expressed whether it is a Lameta fossil as the specimens were found on the surface of a field and it has been suggested that they may have been washed out of some neighbouring intertrappean bed now hidden from view.

In the same neighbourhood, only a few miles distant from Pisdura, fish remains were found by Hislop in supposed Lameta beds at Dhamni and Dongargaon. These were described by Dr. A. Smith Woodward in 1908 (*Pal. Indica*, New Ser., Vol. III, Mem. No. 3). Three species are represented, one Teleostean (*Eoserranus hislopi*) and two Ganoids (*Lepidosteus indicus* and *Pycnodus lametae*). After discussing their affinities Dr. Woodward states that "the age of the Lameta fish-fauna is therefore fixed between the Danian Cretaceous and the Upper Eocene." This evidence is, at first sight, unfavourable to the view expressed in this paper that the Lametas of the Jubbulpore district are probably not newer than Middle Cretaceous; but I believe there is no real conflict of evidence because as a result of a rapid traverse on a bicycle through this country, I came to the conclusion that the Dongargaon beds are not Lametas but are of Intertrappean age. They are of quite a different character from the Lameta rocks around Jubbulpore and differ even from those of Pisdura; they must have been laid down in a separate basin of deposition. As they have not hitherto been described a short account of them may be of interest.

I did not see the base of the Dongargaon beds and cannot say whether they rest on the Trap or on older rocks, but they are undoubtedly covered by Deccan Trap. Near Batára many pieces

[1] Now transferred to the genus *Bullinus*. See Annandale, *Rec. Geol. Surv. India*, Vol. LI, (1920), pp. 50-62.

of cream-coloured or yellow thinly-laminated compact limestone are strewn on the surface of the fields and lie in heaps along the cart-track. In Batára village this limestone is exposed *in situ* and is used on a small scale as a building material. It looks like a rock that should yield fossils, but I found none. It is quite unlike the Lameta limestone around Jubbulpore, and I noted it at the time as "probably an intertrappean band."

More of the Batára limestone can be seen on the way from Batára to Dongargaon where a hill of Trap rises steeply above the general level of the neighbourhood. According to Hughes's map accompanying his memoir on the Wardha Valley Coalfield (*Mem. Geol. Surv. Ind.*, Vol. XIII, 1877, p. 90) Hislop's fossil locality lies to the north of Dongargaon Hill ; it lay off my line of route, and being pressed for time, I did not visit it. Close to Dongargaon village, however, good exposures of sediments are seen below the Trap, dipping in places at 20° to 30°. They consist of greenish and brownish clays with bands of white and cream-coloured limestone and contain casts of tree-stems (or possibly roots) ; in them I also found a gasteropod shell resembling a *Melania*. Between Dongargaon and Pauna is exposed an undoubted intertrappean bed intercalated in the Trap. Between Pauna and Dhamni laminated limestone and sandstone are seen, and, near Dhamni, abundant large calcareous septarian nodules are conspicuous on the surface of the jungle, having the form of flattened spheroids $1\frac{1}{2}$ to 3 feet in diameter. I saw no section of the beds, and as the surface specimens examined contained no fossils and the discovery of Hughes's fossil locality promised to be a matter of some difficulty I returned to Warora without reaching the village of Dhamni.

The whole of this area presents a most interesting facies of lacustrine deposits that are worthy of being mapped in detail and of being searched systematically for fossils. The fossil evidence so far obtained goes to support the view I reached tentatively in the field that these beds lie at a different horizon from those near Lameta Ghat and Jubbulpore. In a great series of lava flows poured out to the thickness of several thousands of feet over an enormous stretch of country many of the later flows must have overlapped the boundaries of earlier flows and transgressed on to the neighbouring sedimentary rocks, any contemporaneous lacustrine beds so covered up being *infra*-trappean in position but *inter*-trappean in age. The extent to which such transgression has taken place must however be

a matter of surmise until a more detailed investigation is made of the stratigraphy of the Deccan Trap and of the sedimentary rocks that fringe them.

In the course of a hurried visit to Pisdura, the author was able to make a few geological observations, which may have some bearing on the point at issue. East and north-east of the village occurs an outlier of Deccan Trap below which comes a group of sediments of which the lowest and most conspicuous zone is a thick bed of red clay, rarely containing green bands and occasionally poikilitic. This bed lies unconformably on white and coloured Kamthi sandstones and was deposited on an irregular surface of them, as the clay seems to fill up small valleys and lap round promontories of the Kamthi beds. Fossils are fairly common in this clay, especially in a ploughed field east of the village of Pisdura, where a short search yielded six caudal vertebræ of *Titanosaurus blanfordi*, Lydekker, and other dinosaurian remains, including a chevron bone and broken limb-bones. A number of large coprolites (probably dinosaurian), portions of a tortoise and about 50 specimens of *Bullinus* (*Physa*) *prinsepii* were found with them. I have no doubt that the mollusca were derived from the red clay. On the east side of the outlier south of the village of Panchgaon further fossils (including another caudal vertebra of *T. blanfordi*) were found. Near this spot many fragments of a thin laminated grey limestone in which a few crushed mollusca were seen lie on the surface of the field and show that a limestone band occurs at or near the top of the red clay. Sandstone and sandy, calcareous and concretionary beds were also seen below the Trap and above the red clay; but owing to lack of time I was unable to examine them.

These beds are locally infra-trappean and are probably of Lameta age as shown on the Geological Survey map, but it is very possible that they are of Inter-trappean age and that the overlying traps are newer than the lowest Deccan traps that overlie the true Lametas of the Jubbulpore District. As *Bullinus* (*Physa*). *prinsepii* has not yet been found in the Lametas elsewhere and as the *Titanosaurus* of Pisdura is of a different species from that found at Jubbulpore, the correlation of the beds at Pisdura with those of Jubbulpore must be for the present considered as somewhat doubtful.

The Middle Jurassic age of the Jabalpur group was fixed by Feistmantel entirely on palæobotanical grounds. But Feistmantel also regarded the flora of the Umia Group of Kachh as Middle Jurassic,

and though he assigned to the Jabalpur group a somewhat lower horizon than that of the Umia, in order to make it conform with the tabular list given in the Manual of the Geology of India, he considered "the difference of the floras not to be so strong as to justify this."[1] As later researches have shown that the Umia beds are not Middle Jurassic but are of Lower Cretaceous age it seems not unlikely that the revision of the fossil flora on which it is understood that Dr. Seward is now engaged may support the stratigraphical evidence adduced in this paper that the Jabalpur beds also are Lower Cretaceous. It should be borne in mind that my remarks refer to the Jabalpur beds of the type area at and near Jubbulpore, because some of the rocks shown on geological maps as Jabalpur beds do not belong to that series; for example, certain sandstones and shales, mentioned on page 150 to the north-east of Silondi, which I have shown to be strongly unconformable to the Lametas, are not at all like the Jabalpur beds of Jubbulpore and almost certainly belong to an older division of the Gondwana System.

The lower Deccan Traps with their intercalated Inter-trappean sediments appear to be not much younger than the Lametas and may prove to be of Middle or Upper Cretaceous age. The fact that "colossal vertebrate bones," unfortunately not capable of identification but almost certainly dinosaurian, were found at Narainpur south of Saugor accompained by *Paludinae*, *Unio deccanensis* and *Bullinus Prinsepii* in beds stated to be Inter-trappean in age, is indicative of a Cretaceous age, because most of the dinosaurs became extinct before Tertiary times. The only area in which dinosaurs are believed to have survived into Lower Tertiary times is North America.

From the above it seems probable that further work will show that the range of the Jabalpur beds to the Lower Deccan Trap will lie wholly in the Cretaceous period, and that the lowest traps may be no younger than Middle Cretaceous.

VII.—ORIGIN OF THE LAMETA LIMESTONE.

The work of Dr. Fermor and Mr. Fox (*Rec. Geol. Surv. India*, Vol. XLIII, 1913, p. 32) in the Chhindwara District shows that the Lameta formation there is usually represented by a thin band of rock intervening between the Deccan Trap and the underlying gneiss. This rock is occasionally a sediment but the greater propor-

[1] *Pal. Indica*, Ser. XI, Pts. 1 and 2, (1880). Preface, page xi.

tion of it is "a rock of chemical origin formed by the silicification or by the calcification of the underlying gneisses," every gradation being found from a fresh porphyritic gneiss to a typical siliceous limestone to be distinguished in no way from the Lameta limestone of other parts of India. As Dr. Fermor found that the limestone of Lameta Ghat itself shows evidence of secondary calcification he is inclined to regard most of the limestones of the formation as of chemical origin, the calcification and silicification of the Lameta sediments when present being probably due to solutions derived from the overlying Deccan Traps, and being thus post-Trappean in age. Similar conclusions to those of Fermor and Fox were arrived at by K. Hallowes from an examination of some calcareous beds found between the gneisses and the Deccan Trap in Hyderabad, South India. (*Rec. Geol. Surv. India*, Vol. XLIX, 1918, pp. 220-222.)

The Lameta rocks of the Jubbulpore district must, therefore, in my opinion be different from those of the Chhindwara district. Instead of the thin calcified and silicified band that separates the gneisses from the Trap at Chhindwara we have several hundred feet of undoubted sediments (Jabalpur and Lameta) intervening between the old crystalline rocks and the base of the Trap. The Main Limestone of the Lametas at Jubbulpore seems to me to be an ordinary sedimentary limestone, that is to say, most of the carbonate of lime in it was there in Lameta times and was not subsequently introduced by infiltration from the overlying Trap, although there has been some chemical alteration in it since its deposition. It has been shown that this limestone zone occupies a constant horizon with a well-marked base separating it clearly and cleanly from the underlying greensand; between it and the Trap intervenes a considerable thickness of other beds the uppermost of which are clean sands showing no infiltration of calcareous matter from above. Further, we find in the place which has yielded dinosaurian bones an ossiferous conglomerate lying at the top of the limestone and containing besides broken bones many pebbles of limestone which can be matched with the underlying rock. This conglomerate shows that the limestone was deposited as a limestone on the top of the greensand and was partly broken up into pebbles by strong currents which introduced the broken reptilian bones found embedded with them. On a theory of subsequent calcification from above it is difficult to understand how the calcareous water could pass through a considerable thickness of other sediments and leave its carbonate of

lime concentrated at a definite horizon in the formation, especially at the top of a highly porous layer like the greensand. On the other hand, the cementing material of the concretions in the Nodular Beds and of the Upper Limestone may possibly have been introduced from the Deccan Trap.

VIII.—SUMMARY AND CONCLUDING REMARKS.

The results of the field work detailed in this paper may be summarised as follows:—

(*i*) There is in the Jubbulpore district an almost continuous sequence of deposits from the Jabalpur Group to the Lowest Deccan Trap.

(*ii*) The Jabalpur group is probably of Lower Cretaceous age, the Lameta Group Albian or Cenomanian or both, and the lowest Deccan traps are possibly no younger than Middle Cretaceous.

(*iii*) The strata near Jubbulpore are affected by a set of parallel post-Trappean strike faults with downthrows to the south-east or south-south-east.

(*iv*) Dinosaurian remains are locally abundant near Jubbulpore and are sparingly but widely distributed in other parts of the Jubbulpore district.

(*v*) The Main Lameta Limestone appears to be an ordinary sedimentary limestone.

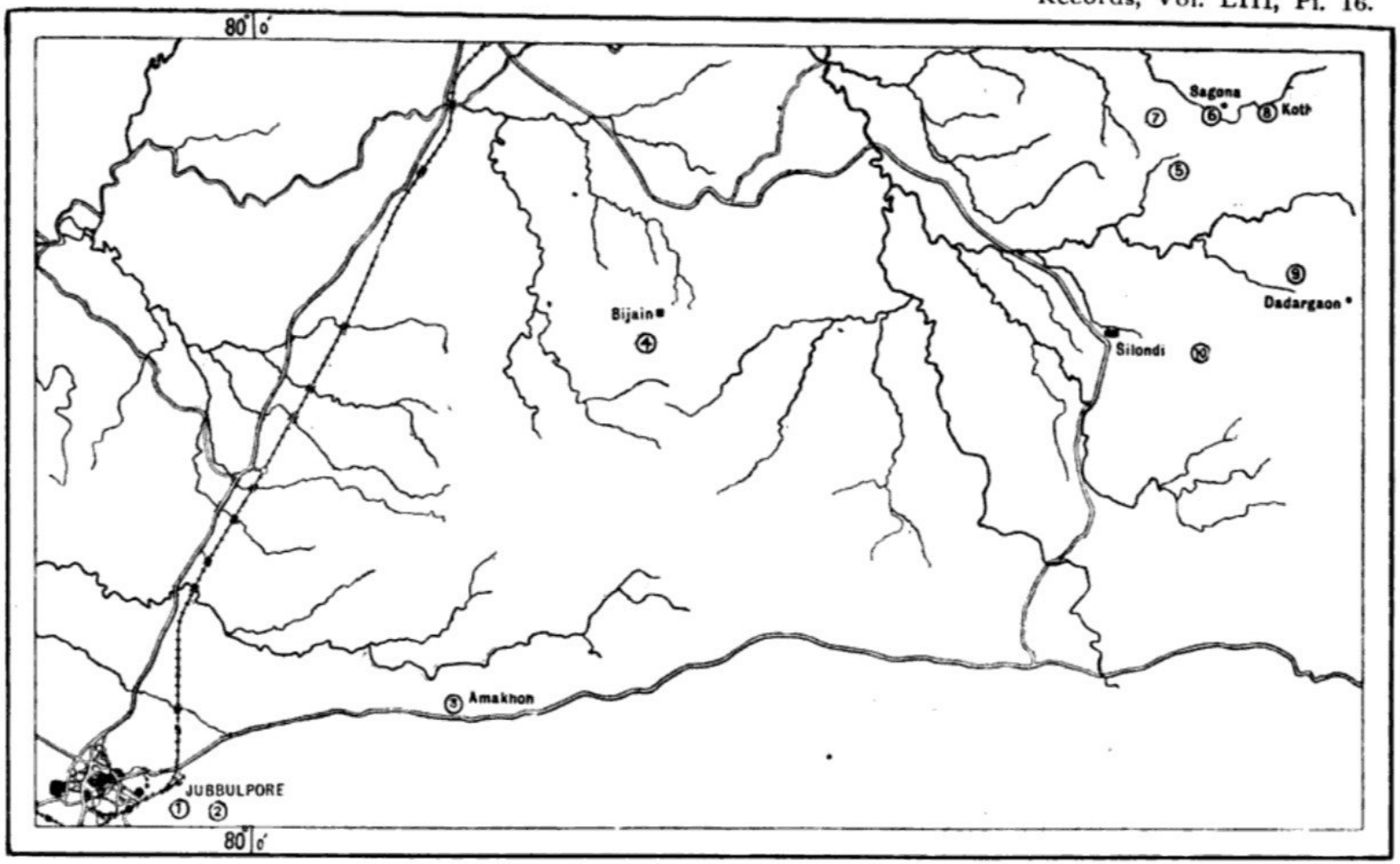
In conclusion I beg to tender my best thanks to the officers of the Geological Survey of India, especially the Director and the Curator, for valuable help and facilities for work both in the field and in the laboratory.

EXPLANATION OF PLATES.

PLATE 16.—Sketch map of the Jubbulpore District showing Dinosaurian fossil localities: Scale 1 inch=6 miles.

PLATE 17.—Fig. 1. Geological Section along the line A B on plate 18.
Fig. 2. Geological Section along the line C D on plate 18.

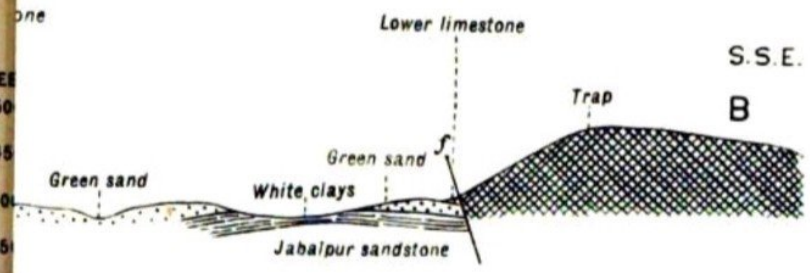
PLATE 18.—Geological map of part of Jubbulpore Cantonment: Scale 8 inches =1 mile.



G. S. I. Calcutta.

SKETCH MAP OF THE JUBBULPORE DISTRICT SHOWING DINOSAURIAN FOSSIL LOCALITIES.

Scale 1 inch = 6 miles.



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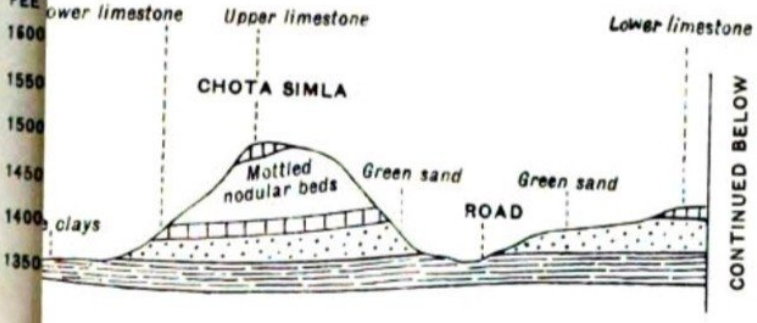

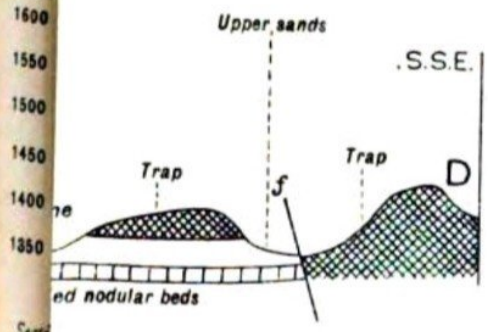

Litho. G. S. I. Calcutta.